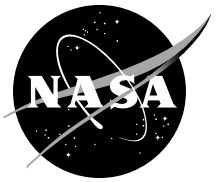
NASA/TM—1999–209149



FY 1998 Scientific and Technical Reports, Articles, Papers, and Presentations

Compiled by
J.E. Turner Waits
Marshall Space Flight Center, Marshall Space Flight Center, Alabama

March 1999

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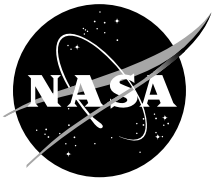

FY 1998 Scientific and Technical Reports, Articles, Papers, and Presentations

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March 1999

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FOREWORD

In accordance with the NASA Space Act of 1958, the MSFC has provided for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

Since July 1, 1960, when the George C. Marshall Space Flight Center was organized, the reporting of scientific and engineering information has been considered a prime responsibility of the Center. Our credo has been that “research and development work is valuable, but only if its results can be communicated and made understandable to others.”

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GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama

FY 1998 SCIENTIFIC AND TECHNICAL REPORTS
ARTICLES, PAPERS, AND PRESENTATIONS

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TM—97–206310 November 1997

Investigation of the Springback Associated With Composite Material Component Fabrication (MSFC Center Director's Discretionary Fund Final Report, Project No. 94–09). M.A. Benzie. Materials and Processes Laboratory. 19980007549N

The objective of this research project was to examine processing and design parameters in the fabrication of composite components to obtain a better understanding and attempt to minimize springback associated with composite materials. To accomplish this, both processing and design parameters were included in a Taguchi-designed experiment. Composite angled panels were fabricated, by hand layup techniques, and the fabricated panels were inspected for springback effects. This experiment yielded several significant results. The confirmation experiment validated the reproducibility of the factorial effects, error recognized, and experiment as reliable. The material used in the design of tooling needs to be a major consideration when fabricating composite components, as expected. The factors dealing with resin flow, however, raise several potentially serious material and design questions. These questions must be dealt with up front in order to minimize springback: viscosity of the resin, vacuum bagging of the part for cure, and the curing method selected. These factors directly affect design, material selection, and processing methods.

TM—97–206317 November 1997

The Impact Response of Carbon/Epoxy Laminates (MSFC Center Director's Discretionary Fund Final Report, Project No. 94–13). A.T. Nettles and A.J. Hodge. Materials and Processes Laboratory. 19980009327N

Low velocity dropweight impact tests were conducted on carbon/epoxy laminates under various boundary conditions. The composite plates were 8-ply (+45,0,–45,90)s laminates supported in a clamped-clamped/free-free configuration with varying amounts of in-plane load, Nx, applied. Specimens were impacted at energies of 3.4, 4.5, and 6 Joules (2.5, 3.3, and 4.4 ft-lb). The amount of damage induced into the specimen was evaluated using instrumented impact techniques, x-ray inspection, and cross-sectional photomicroscopy. Some static identation tests were performed to examine if the impact events utilized in this study were of a quasi-static nature and also to gain insight into the shape of the deflected surface at various impact load combinations. Load-displacement curves from these tests were compared to those of the impact tests, as was damage determined from x-ray inspection. The finite element technique was used to model the impact event and determine the stress field within the laminae.

Results showed that for a given impact energy level, more damage was induced into the specimen as the external in-plane load, Nx, was increased. The majority of damage observed consisted of back face splitting of the matrix parallel to the fibers in that ply, associated with delaminations emanating from these splits. The analysis showed qualitatively the results of impact conditions on maximum load of impact, maximum transverse deflection, and first failure mode and location.

TM—1998–206528 March 1998

ISWE: A Case Study of Technology Utilization. M.P. Benfield, D.P. Mitchell, M.T. Vanhooser, and D.B. Landrum. Systems Analysis and Integration Laboratory. 19980027602N

The International Space Welding Experiment is a joint project between the E.O. Paton Welding Institute of Kiev, Ukraine and the George C. Marshall Space Flight Center in Huntsville, Alabama. When an international partner is involved in a project, differences in design and testing philosophy can become a factor in the development of the hardware. This report addresses selected issues that arose during the ISWE hardware development as well as the solutions the ISWE team made.

TM—1998–206953 January 1998

Damping Mechanisms for Microgravity Vibration Isolation (MSFC Center Director's Discretionary Fund Final Report, Project No. 94–07). M.S. Whorton, J.T. Eldridge, R.C. Ferebee, J.O. Lassiter, and J.W. Redmon, Jr. Structures and Dynamics Laboratory. 19980017169N

As a research facility for microgravity science, the *International Space Station* (*ISS*) will be used for numerous investigations such as protein crystal growth, combustion, and fluid mechanics experiments which require a quiescent acceleration environment across a broad spectrum of frequencies. These experiments are most sensitive to low-frequency accelerations and can tolerate much higher accelerations at higher frequency. However, the anticipated acceleration environment on *ISS* significantly exceeds the required acceleration level. The ubiquity and difficulty in characterization of the disturbance sources precludes source isolation, requiring vibration isolation to attenuate the anticipated disturbances to an acceptable level. This memorandum reports the results of research in active control methods for microgravity vibration isolation.

TM—1998–206956/VOL1 January 1998

Living Together in Space: The Design and Operation of the Life Support Systems on the *International Space Station*, VOL1. P.O. Wieland. Structures and Dynamics Laboratory. 19980037427N

The *International Space Station* (*ISS*) incorporated elements designed and developed by an international consortium led by the United States (U.S.), and by Russia. For this cooperative effort to succeed, it is crucial that the designs and methods of design of the other partners are understood sufficiently to ensure compatibility. Environmental Control and Life Support (ECLS) is one system in which functions are performed independently on the Russian Segment (RS) and on the U.S./international segments. This document describes, in two volumes, the design and operation of the ECLS Systems (ECLSS) on board the *ISS*. Volume I is divided into three chapters. Chapter I is a general overview of the *ISS*, describing the configuration, general requirements, and distribution of systems as related to the ECLSS, and includes discussion of the design philosophies of the partners and methods of verification of equipment. Chapter II describes the U.S. ECLSS and technologies in greater detail. Chapter III described the ECLSS in the European Attached Pressurized Module (APM), Japanese Experiment Module (JEM), and Italian Mini-Pressurized Logistics Module (MPLM). Volume II describes the Russian ECLSS and technologies in greater detail. These documents present thorough, yet concise, descriptions of the *ISS* ECLSS.

TM—1998–207195 February 1998

Database for the Tribological Properties of Self-Lubricating Materials. T.R. Jett and R.L. Thom. Materials and Processes Laboratory. 19980039325N

A test program to determine the tribological properties of several self-lubricating composites was performed. Testing was done using an LFW–1 Friction and Wear machine. Each material was tested at four load levels (66 N, 133 N, 266 N, and 400 N) under ambient conditions. The coefficient of friction and wear rate was determined for each material, and a relative ranking of the composites was made.

TM—1998–207685 March 1998

Measurement of Damping of Composite Materials for Turbomachinery Applications (MSFC Center Director's Discretionary Fund Final Report, Project No. 94–05). D.L. Harris. Structures and Dynamic Laboratory.

The scientific community has felt that ceramic matrix composite (CMC) materials possess more material damping than the superalloys used in the production of rocket engine turbomachinery turbine-end components. The purpose of this NASA/MSFC study is to quantify the damping in CMC's as compared to a typical superalloy, Inconel 718. It was observed through testing of beam coupons and disk specimens that the CMC's do indeed possess more material damping than the baselined alloy Inconel 718.

TM—1998–207891 April 1998

Third United States Microgravity Payload: One Year Report. P.A. Curreri, D. McCauley,* and C. Walker,** Editors, Space Sciences Laboratory, University of Alabama in Huntsville.* Universities Space Research Association.**

This document reports the one year science results for the Third United States Microgravity Payload (USMP-3). The USMP-3 major experiments were on a support structure in the Space Shuttle's payload bay and operated almost completely by the Principal Investigators through telescience. The mission included a Glovebox where the crew performed additional experiments for the investigators. Together about seven major scientific experiments were performed advancing the state of knowledge in fields such as low temperature physics, solidification, and combustion. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity and provide a look forward to a highly productive space station era.

TM—1998–207945 May 1998

High Performance, Robust Control of Flexible Space Structures (MSFC Center Director's Discretionary Fund Final Report, Project No. 96–23). M.S. Whorton. Structures and Dynamics Laboratory. 19980137576N

Many spacecraft systems have ambitious objectives that place stringent requirements on control systems. Achievable performance is often limited because of difficulty of obtaining accurate models for flexible space structures. To achieve sufficiently high performance to accomplish mission objectives may require the ability to refine the control design model based on closed-loop test data and tune the controller based on the refined model. A control system design procedure is developed based on mixed H_2/H_∞ optimization to synthesize a set of controllers explicitly trading between nominal

performance and robust stability. A homotopy algorithm is presented which generates a trajectory of gains that may be implemented to determine maximum achievable performance for a given model error bound. Examples show that a better balance between robustness and performance is obtained using the mixed H_2/H_∞ design method than either H_2 or mu-synthesis control design. A second contribution is a new procedure for closed-loop system identification which refines parameters of a control design model in a canonical realization. Examples demonstrate convergence of the parameter estimation and improved performance realized by using the refined model for controller redesign. These developments result in an effective mechanism for achieving high-performance control of flexible space structures.

TM—1998–207979 May 1998

An Assessment of Molten Metal Detachment Hazards for Electron Beam Welding in the Space Environment: Analysis and Test Results. A.C. Nunes, Jr., J.M. Fragomeni,* C. Russell, and B. Bhat. Materials and Processes Laboratory, and *Ohio University. 19980119852N

Conditions under which molten metal detachments might occur in a space welding environment are analyzed. A weld pool detachment parameter specifying conditions for pool detachment by impact is derived and corroborated by experimental evidence. Impact detachment for the pool is unlikely. Impact detachment for a drop of metal on the end of the weld wire may be possible under extreme conditions. Other potential causes of molten metal detachment considered, vaporization pressure forces and wire flickout from the pool, did not appear to present significant detachment threats.

TM—1998–208181 May 1998

Mirror Material Properties Compiled for Preliminary Design of the Next Generation Space Telescope (30 to 249 Kelvin). P.L. Luz and T. Rice. Preliminary Design Office. 19980201336N

This technical memorandum reports on the mirror material properties that were compiled by NASA Marshall Space Flight Center (MSFC) from April 1996 to June 1997 for preliminary design of the Next Generation Space Telescope (NGST) study. The NGST study began in February 1996, when the Program Development Directorate at NASA MSFC studied the feasibility of the NGST and developed the prephase A program for it. After finishing some initial studies and concepts development work on the NGST, MSFC's Program Development Directorate handed this work to the Observatory Projects Office at MSFC and then to NASA Goddard Space Flight Center (GSFC). This technical memorandum was written by MSFC's Preliminary Design Office and Materials and Processes Laboratory for the NGST Optical Telescope Assembly (OTA) team, in support of NASA GSFC. It contains material properties for 9 mirror substrate materials, using information from at least 6 industrial suppliers, 16 textbooks, 44 technical papers, and 130 technical abstracts.

TM—1998–208194 May 1998

Thruster Injector Faceplate Testing in Support of the Aerojet Rocket-Based Combined Cycle (RBCC) Concept. M.M. Fazah and J.M. Cramer. Propulsion Laboratory. 19980201177N

To satisfy RBCC rocket thruster requirements of high performance and a minimum amount of free hydrogen at plume boundary, a new impinging injector element using gaseous hydrogen and gaseous oxygen as the propellants has been designed. Analysis has shown that this injector design has potential to provide a high specific impulse (Isp) while minimizing the amount of free hydrogen that is available to be burned with incoming secondary flow. Past studies and test programs have shown that gas/gas-impinging elements typically result in high injector face temperatures due to combustion occurring close to the face. Since this design is new, there is no hot fire experience with this element. Objectives of this test program were to gain experience and hot fire test data on this new rocket thruster element design and injector faceplate pattern.

Twenty-two hot fire tests were run with maximum mixture ratio (MR) and chamber pressure (Pc) obtained at 7.25 and 1,822 psia, respectively. Posttest scanning microscope (SEM) images show only slight faceplate erosion during testing. This injector element design performed well and can be operated at design conditions: (1) Pc of 2,000 psia and MR of 7.0 and (2) Pc of 1,000 psia of 1,000 psia and MR of 5.0.

TM—1998–208418 June 1998

NASA's Microgravity Research Program 1997 Annual Report. D. Woodard, Editor. Microgravity Research Program Office.

The Fiscal Year 1997 Annual Report describes key elements of the NASA Microgravity Research Program. The Program's goals, approach taken to achieve those goals, and program resources are summarized. A review of the Program's status at the end of FY97 and highlights of the ground- and flight-based research are provided.

TM—1998–208472 June 1998

Preliminary In-Flight Loads Analysis of In-Line Launch Vehicles Using the VLOADS 1.4 Program. J.B. Graham and P.L. Luz. Preliminary Design Office. 19980201045N

To calculate structural loads of in-line launch vehicles for preliminary design, a very useful computer program is VLOADS 1.4. This software may also be used to calculate structural loads for upper stages and planetary transfer vehicles. Launch vehicle inputs such as aerodynamic coefficients, mass properties, propellants, engine thrusts, and performance data are compiled and analyzed by VLOADS to produce distributed shear loads, bending moments, axial forces, and vehicle line loads as a function of X-station along the vehicle's length. Interface loads, if any, and translational accelerations are also computed. The major strength of the software is that it enables quick turnaround analysis of structural loads for launch vehicles during the preliminary design stage of its development. This represents a significant improvement over the alternative—the time-consuming and expensive chore of developing finite element models. VLOADS was developed as a Visual BASIC macro in a Microsoft Excel 5.0 workbook on a Macintosh. VLOADS has also been implemented on a PC computer using Microsoft Excel 7.0a for Windows 95. VLOADS was developed in 1996, and the current version was released to COSMIC, NASA's Software Technology Transfer Center, in 1997. The program is a copyrighted work with all copyright vested in NASA.

TM—1998–208473 June 1998

Development of a Probabilistic Dynamic Synthesis Method for the Analysis of Nondeterministic Structures. A.M. Brown. Structures and Dynamics Laboratory.

Accounting for variability of structures in analysis has been a topic of considerable research, with one of the primary goals being able to determine quantifiable measures of statistical probability of a desired response variable to replace experience-based "safety factors." Several problems with the satisfactory application of this research to realistic structures, though, include accurate definition of the input random variables, the large size of finite element models, and accurate generation of the Cumulative Distribution Function (CDF) of the response variable. A new method called "probabilistic dynamic synthesis" (PDS) is presented here that addresses these problems. The PDS method uses dynamic characteristics of substructures measured from modal test as input random variables, which accurately account for the entire random character of the substructure, rather than "primitive" random variables representing material or geometric uncertainties. Using the residual flexibility method of component mode synthesis, these dynamic characteristics are used to generate reduced-size sample models of the substructures, which are then used in a Monte Carlo simulation or in the response surface reliability method to obtain the CDF. Both free and forced analyses have been performed, and the results indicate that the method produces usable and more representative solutions for the design of realistic structures with a substantial savings in computer time.

TM—1998–208529 July 1998

A Case Study for Probabilistic Methods Validation (MSFC Center Director's Discretionary Fund Final Report, Project 94–26). J.M. Price and R. Ortega. Structures and Dynamics Laboratory. 19980211463N

Probabilistic method is not a universally accepted approach for the design and analysis of aerospace structures. The validity of this approach must be demonstrated to encourage its acceptance as a viable design and analysis tool to estimate structural reliability. The objective of this study is to develop a well characterized finite population of similar aerospace structures that can be used to (1) validate probabilistic codes, (2) demonstrate the basic principles behind probabilistic methods, (3) formulate general guidelines for characterization of material drivers (such as elastic modulus) when limited data is available, and (4) investigate how the drivers affect the results of sensitivity analysis at the component/failure mode level.

TM—1998–208532 July 1998

NASA's Microgravity Technology Report—Summary of Activities 1997. D. Woodard, Editor. Microgravity Research Program.

The purpose of the 1997 NASA Microgravity Technology Report is to update the Microgravity Research Program's technology development policy and to present and assess current technology related activities and requirements identified within its research and technology disciplines.

TM—1998–208533 July 1998

Interplanetary Mission Design Handbook: Earth-to-Mars Mission Opportunities and Mars-to-Earth Return Opportunities 2004–2024. L.E. George* and L.D. Kos. *U.S. Air Force Academy, Preliminary Design Office. 19980210557N

This paper provides information for trajectory designers and mission planners to determine Earth-Mars and Mars-Earth mission opportunities for the years 2009–2024. These studies were performed in support of a human Mars mission scenario that will consist of two cargo launches followed by a piloted mission during the next opportunity approximately 2 years later. "Porkchop" plots defining all of these mission opportunities are provided which include departure energy, departure excess speed, departure declination arrival excess speed, and arrival declinations for the mission space surrounding each opportunity. These plots are intended to be directly applicable for the human Mars mission scenario described briefly herein. In addition, specific trajectories and several alternate trajectories are recommended for each cargo and piloted opportunity. Finally, additional studies were performed to evaluate the effect of various thrust-to-weight ratios on gravity losses and total time-of-flight tradeoff, and the resultant propellant savings and are briefly summarized.

TM—1998–208534 July 1998

Space Sciences Laboratory Publications and Presentations January 1–December 31, 1997. F.G. Summers, Compiler. Space Sciences Laboratory.

This document lists the significant publications and presentations of the Space Sciences Laboratory during the period January 1–December 31, 1997. Entries in the main part of the document are categorized according to NASA Reports (arranged by report number), Open Literature, and Presentations (arranged alphabetically by title). Also included for completeness is an Appendix (arranged by page number) listing preprints issued by the Laboratory during this reporting period. Some of the preprints have not been published; those already published are so indicated. Most of the articles listed under Open Literature have appeared in refereed professional journals, books, monographs, or conference proceedings. Although many published abstracts are eventually expanded into full papers for publication in scientific and technical journals, they are often sufficiently comprehensive to include the significant results of the research reported. Therefore, published abstracts are listed separately in a subsection under Open Literature. Questions or requests for additional information about the entries in this report should be directed to Gregory S. Wilson (ES01; 544–7579) or to one of the authors. The organizational code of the cognizant SSL branch or office is given at the end of each entry.

TM—1998–208538 July 1998

International Space Station Electrodynamic Tether Reboost Study. L. Johnson and M. Herrmann. Program Development Directorate.

The *International Space Station* (*ISS*) will require periodic reboost due to atmospheric aerodynamic drag. This is nominally achieved through the use of thruster firings by the attached Progress M spacecraft. Many Progress flights to the *ISS* are required annually. Electrodynamic tethers provide an attractive alternative in that they can provide periodic reboost or continuous drag cancellation using no consumables, propellant, nor conventional propulsion elements. The system could also serve as an emergency backup reboost system used only in the event resupply and reboost are delayed for some reason.

TM—1998–208539 August 1998

Final Report on Life Testing of the Vapor Compression Distillation/Urine Processing Assembly (VCD/UPA) at the Marshall Space Flight Center (1993 to 1997). P. Wieland, C. Hutchens, D. Long, and B. Salyer,* Structures & Dynamics Laboratory, Science and Engineering Directorate, *Ion Electronics. 19980211458N

Wastewater and urine generated on the *International Space Station* will be processed to recover pure water using vapor compression distillation (VCD). To verify the long-term reliability and performance of the VCD Urine Processor Assembly (UPA), life testing was performed at the Marshall Space Flight Center (MSFC) from January 1993 to April 1996. Two UPA's, the VCD-5 and VCD-5A, were tested for 204 days and 665 days, respectively. The compressor gears and the distillation centrifuge drive belt were found to have operating lives of approximately 4,800 hours, equivalent to 3.9 years of operation on *ISS* for a crew of three at an average processing rate of 1.76 kg/h (3.87 lb/h). Precise alignment of the flex-splines of the fluids and purge pump motor drives is essential to avoid premature failure after about 400 hours of operation. Results indicate that, with some design and procedural modifications and suitable quality control, the required performance and operational life can be met with the VCD/UPS.

TM—1998–208594 August 1998

Comprehensive Structural Dynamic Analysis of the SSME/AT Fuel Pump First-Stage Turbine Blade. A.M. Brown. Structures and Dynamics Laboratory. 19980217661N

A detailed structural dynamic analysis of the Pratt & Whitney high-pressure fuel pump first-stage turbine blades has been performed to identify the cause of the tip cracking found in the turbomachinery in November 1997. The analysis was also used to help evaluate potential fixes for the problem. Many of the methods available in structural dynamics were applied, including modal displacement and stress analysis, frequency and transient response to tip loading from the first-stage blade outer gas seals (BOGS), fourier analysis, and shock spectra analysis of the transient response. The primary findings were that the BOGS tip loading is impulsive in nature, thereby exciting many modes of the blade that exhibit high stress at the tip cracking location. Therefore, a proposed BOGS count change would not help the situation because a clearly identifiable resonance situation does not exist. The recommendations for the resolution of the problem are to maintain the existing BOGS count, eliminate the stress concentration in the blade due to its geometric design, and reduce the applied load on the blade by adding shiplaps in the BOGS.

TM—1998–208697/VOL1 August 1998

Second United States Microgravity Laboratory. One Year Report, Volume 1. M. Vlasse, D. McCauley, and C. Walker.

This document reports the one year science results for the important and highly successful Second United States Microgravity Laboratory (USML–2). The USML–2 mission consisted of a pressurized Space lab module where the crew performed experiments. The mission also included a Glovebox where the crew performed additional experiments for the investigators. Together, about 36 major scientific experiments were performed, advancing the state of knowledge in fields such as fluid physics, solidification of metals, alloys, and semiconductors, combustion, and the growth of protein crystals. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity and provide a look forward to a highly productive Space Station era.

TM—1998–208697/VOL2 August 1998

Second United States Microgravity Laboratory. One Year Report, Volume 2. M. Vlasse, D. McCauley, and C. Walker.

This document reports the one year science results for the important and highly successful Second United States Microgravity Laboratory (USML–2). The USML–2 mission consisted of a pressurized Space lab module where the crew performed experiments. The mission also included a Glovebox where the crew performed additional experiments for the investigators. Together, about 36 major scientific experiments were performed, advancing the state of knowledge in fields such as fluid physics, solidification of metals, alloys, and semiconductors, combustion, and the growth of protein crystals. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity and provide a look forward to a highly productive Space Station era.

TM—1998–208801 August 1998

FY 1997 Scientific and Technical Reports, Articles, Papers, and Presentations. J.E. Turner Waits, Compiler. Technical Information and Operations Services Office.

This document presents formal NASA technical reports, papers published in technical journals, and presentations by MSFC personnel in FY97. It also includes papers of MSFC contractors.

After being announced in STAR, all of the NASA series reports may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

The information in this report may be of value to the scientific and engineering community in determining what information has been published and what is available.

TM—1998–208804 September 1998

Model-Based Diagnosis in a Power Distribution Test-Bed. E. Scarl* and K. McCall. Astrionics Laboratory. *The Boeing Company, Huntsville, AL.

The Rodon model-based diagnosis shell was applied to a breadboard test-bed, modeling an automated power distribution system. The constraint-based modeling paradigm and diagnostic algorithm were found to adequately represent the selected set of test scenarios.

TP—97–206238 November 1997

Inherent Conservatism in Deterministic Quasi-Static Structural Analysis. V. Verderaime. Structures and Dynamics Laboratory. 19980006779N

The cause of the long-suspected excessive conservatism in the prevailing structural deterministic safety factor has been identified as an inherent violation of the error propagation laws when reducing statistical data to deterministic values and then combining them algebraically through successive structural computational processes. These errors are restricted to the applied stress computations, and because mean and variations of the tolerance limit format are added, the errors are positive, serially cumulative, and excessively conservative. Reliability methods circumvent these errors and provide more efficient and uniform safe structures. The document is a tutorial on the deficiencies and nature of the current safety factor and of its improvement and transition to absolute reliability.

TP—97–206239 November 1997

The Corrosion Protection of Magnesium Alloy AZ31B. M.D. Danford, M.J. Mendrek, M.L. Mitchell, and P.D. Torres. Materials and Processes Laboratory. 19980006782N

Corrosion rates for bare and coated Magnesium alloy AZ31B have been measured. Two Coatings, Dow-23™ and Tagnite,™ have been tested by electrochemical methods and their effectiveness determined. Electrochemical methods employed were the scanning reference electrode technique (SRET), the polarization resistance technique (PR) and the electrochemical impedance spectroscopy technique (EIS). In addition, general corrosion and stress corrosion methods were employed to examine the effectiveness of the above coatings in 90 percent humidity. Results from these studies are presented.

TP—97–206311 November 1997

SEDS Tether M/OD Damage Analyses. K.B. Hayashida, J.H. Robinson, and S.A. Hill. Structures and Dynamics Laboratory. 19980006778N

The Small Expandable Deployer System (SEDS) was designed to deploy an endmass at the end of a 20-km-long tether which acts as an upper stage rocket, and the threats from the meteoroid and orbital debris (M/OD) particle environments on SEDS components are important issues for the safety and success of any SEDS mission. However, the possibility of severing the tether due to M/OD particle impacts is an even more serious concern, since the SEDS tether has a relatively large exposed area to the M/OD environments although its diameter is quire small. The threats from the M/OD environments became a very important issue for the third SEDS mission, since the project office proposed using the shuttle orbiter as a launch platform instead of the second stage of a Delta II expendable rocket, which was used for the first two SEDS mission.

A series of hypervelocity impact tests were performed at the Johnson Space Center and Arnold Engineering Development Center to help determine the critical particle sizes required to sever the tether. The computer hydrodynamic code or hydrocode called CTH, developed by the Sandia National Laboratories, was also used to simulate the damage on the SEDS tether caused by both the orbital debris and test particle impacts. The CTH hydrocode simulation results provided the much needed information to help determine the critical particle sizes required to sever the tether. The M/OD particle sizes required to sever the tether were estimated to be less than 0.1 cm in diameter from these studies, and these size particles are more abundant in low-Earth orbit than larger size particles. Finally, the authors performed the M/OD damage analyses for the three SEDS missions; i.e., SEDS–1, –2, and –3 missions, by using the information obtained from the hypervelocity impact test and hydrocode simulations results.

TP—1998–206952 January 1998

Corrosion Studies of 2195 Al-Li Alloy and 2219 Al Alloy with Differing Surface Treatments. M.D. Danford and M.J. Mendrek. Materials and Processes Laboratory. 19980019510N

Corrosion studies of 2195 Al-Li and 2219 Al alloys have been conducted using the scanning reference electrode technique (SRET) and the polarization resistance (PR) technique. The SRET was used to study corrosion mechanisms, while corrosion rate measurements were studied with the PR technique. Plates of Al_2O_3 blasted, soda blasted and conversion coated 2219 Al were coated with Deft primer and the corrosion rates studied with the EIS technique. Results from all of these studies are presented.

TP—1998–206959 March 1998

Tether Transportation System Study. M.E. Bangham,* E. Lorenzini,** and L. Vestal. Program Development Directorate. *Boeing, Huntsville, AL. **Smithsonian Astrophysical, Cambridge, MA. 19980048417N

The projected traffic to geostationary earth orbit (GEO) is expected to increase over the next few decades. At the same time, the cost of delivering payloads from the Earth's surface to low earth orbit (LEO) is projected to decrease, thanks in part to the Reusable Launch Vehicle (RLV). A comparable reduction in the cost of delivering payloads from LEO to GEO is sought. The use of in-space tethers, eliminating the requirement for traditional chemical upper stages and thereby reducing the launch mass, has been identified as such an alternative.

Spinning tethers are excellent kinetic energy storage devices for providing the large delta vee's required for LEO to GEO transfer. A single-stage system for transferring payloads from LEO to GEO was proposed some years ago. The study results presented here contain the first detailed analyses of this proposal, its extension to a two-stage system, and the likely implementation of the operational system.

TP—1998–207194 March 1998

Probability and Statistics in Aerospace Engineering. M.H. Rheinfurth and L.W. Howell. Systems Analysis and Integration Laboratory. 19980045313N

This monograph was prepared to give the practicing engineer a clear understanding of probability and statistics with special consideration to problems frequently encountered in aerospace engineering. It is conceived to be both a desktop reference and a refresher for aerospace engineers in government and industry. It could also be used as a supplement to standard texts for in-house training courses on the subject.

TP—1998–207399 March 1998

A Study of Friction Stir Welded 2195 Al-Li Alloy by the Scanning Reference Electrode Technique. M.D. Danford and M.J. Mendrek. Materials and Processes Laboratory. 19980046577N

A study of the corrosion of friction stir welded 2195 Al-Li alloy has been carried out using the scanning reference electrode technique (SRET). The results are compared to those obtained from a study of heterogeneously welded samples.

TP—1998–207686 April 1998

Comparative Stress Corrosion Cracking and General Corrosion Resistance of Annealed and Hardened 440C Stainless Steel—New Techniques in Stress Corrosion Testing. M.J. Mendrek, B.E. Hurless, P.D. Torres, and M.D. Danford. Materials and Processes Laboratory. 19980053568

The corrosion and stress corrosion cracking (SCC) characteristics of annealed and hardened 440C stainless steel were evaluated in high humidity and 3.5-percent NaC1 solution. Corrosion testing consisted of an evaluation of flat plates, with and without grease, in high humidity, as well as electrochemical testing in 3.5-percent NaC1. Stress corrosion testing consisted of conventional constant strain, smooth bar testing in high humidity in addition to two relatively new techniques under evaluation at MSFC. These techniques involve either incremental or constant rate increases in the load applied to a precracked SE(B) specimen, monitoring the crack-opening-displacement response for indications of crack growth. The electrochemical corrosion testing demonstrated an order of magnitude greater general corrosion rate in the annealed 440C. All techniques for stress corrosion testing showed substantially better SCC resistance in the annealed material. The efficacy of the new techniques for stress corrosion testing was demonstrated both by the savings in time and the ability to better quantify SCC data.

TP—1998–208396 May 1998

Application of Rapid Prototyping Methods to High-Speed Wind Tunnel Testing (MSFC Center Director's Discretionary Fund Final Report, Project No. 96–21). A.M. Springer. Structures and Dynamics Laboratory. 19980201248 N

This study was undertaken in MSFC's 14-Inch Trisonic Wind Tunnel to determine if rapid prototyping methods could be used in the design and manufacturing of high speed wind tunnel models in direct testing applications, and if these methods would reduce model design/fabrication time and cost while providing models of high enough fidelity to provide adequate aerodynamic data, and of sufficient strength to survive the test environment. Rapid prototyping methods utilized to construct wind tunnel models in a wing-body-tail configuration were: fused deposition method using both ABS plastic and PEEK as building materials, stereolithography using the photopolymer SL–5170, selective laser sintering using glass reinforced nylon, and laminated object manufacturing using plastic reinforced with glass and "paper."

This study revealed good agreement between the SLA model, the metal model with an FDM–ABS nose, and SLA nose, and the metal model for most operating conditions, while the FDM–ABS data diverged at higher loading conditions. Data from the initial SLS model showed poor agreement due to problems in post-processing, resulting in a different configuration. A second SLS model was tested and showed relatively good agreement.

It can be concluded that rapid prototyping models show promise in preliminary aerodynamic development studies at subsonic, transonic, and supersonic speeds.

TP—1998–208475 June 1998

Electrodynamic Tether Propulsion and Power Generation at Jupiter. D.L. Gallagher, L. Johnson, J. Moore,* Program Development Directorate, SRS Technologies,* and F. Bagenal.** University of Colorado.**

19980203952N

The results of a study performed to evaluate the feasibility and merits of using an electrodynamic tether for propulsion and power generation for a spacecraft in the Jovian system are presented. The environment of the Jovian system has properties which are particularly favorable for utilization of an electrodynamic tether. Specifically, the planet has a strong magnetic field and the mass of the planet dictates high orbital velocities which, when combined with the planet's rapid rotation rate, can produce very large relative velocities between the magnetic field and the spacecraft. In a circular orbit close to the planet, tether propulsive forces are found to be as high as 50 N and power levels as high as 1 MW.

TP—1998–208528 July 1998

An Assessment of the Technology of Automated Rendezvous and Capture in Space. M.E. Polites. Astrionics Laboratory. 19980219470N

This paper presents the results of a study to assess the technology of automated rendezvous and capture (AR&C) in space. The outline of the paper is as follows. First, the history of manual and automated rendezvous and capture and rendezvous and dock is presented. Next, the need for AR&C in space is established. Then, today's technology and ongoing technology efforts related to AR&C in space are reviewed. In light of these, AR&C systems are proposed that meet NASA's future needs, but can be developed in a reasonable amount of time with a reasonable amount of money. Technology plans for developing these systems are presented; cost and schedule are included.

TP—1998–208530 July 1998

Reusable Rocket Engine Operability Modeling and Analysis. R.L. Christenson and D.R. Komar. Propulsion Laboratory. 19980218686N

This paper described the methodology, model, input data, and analysis results of a reusable launch vehicle engine operability study conducted with the goal of supporting design from an operations perspective. Paralleling performance analyses in schedule and method, this requires the use of metrics in a validated operations model useful for design, sensitivity, and trade studies. Operations analysis in this view is one of several design functions.

An operations concept was developed given an engine concept and the predicted operations and maintenance processes incorporated into simulation models. Historical operations data at a level of detail suitable to model objectives were collected, analyzed, and formatted for use with the models, the simulations were run, and results collected and presented. The input data used included scheduled and unscheduled timeline and resource information collected into a Space Transportation System (STS) Space Shuttle Main Engine (SSME) historical launch operations database. Results reflect upon the importance not only of reliable hardware but upon operations and corrective maintenance process improvements.

TP—1998–208591 August 1998

On the Correlation Between Maximum Amplitude and Smoothed Monthly Mean Sunspot Number During the Rise of the Cycle (From t=0–48 Months Past Sunspot Minimum). R.M. Wilson, D.H. Hathaway, and E.J. Reichmann. Space Sciences Laboratory.

During the rise from sunspot minimum to maximum, the observed value of smoothed monthly mean sunspot number at maximum RM is found to correlate with increasing strength against the current value of smoothed monthly mean sunspot number R(t), where t is the elapsed time in months from minimum. On the basis of the modern era sunspot cycles (i.e., cycles 10–22), the inferred linear correlation is found to be statistically important (i.e., at the 95-percent level of confidence) from about 11 mo past minimum and statistically very important (i.e., at the 99-percent level of confidence) from about 15 mo past minimum; ignoring cycle 19, the largest cycle of the modern era, the inferred linear correlation is found to be statistically important from cycle onset. On the basis of $R(t)$, estimates of RM can be gauged usually to within about ±30 percent during the first 2 yr and to within about ±20 percent (or better) after the first 2 hr of a cycle's onset. For cycle 23, because controversy exists regarding the placement of its minimum (i.e., its onset), being either May 1996 or perhaps August 1996 (or shortly thereafter), estimates of its RM are divergent, being lower (more like a mean size cycle) when using the earlier epoch of minimum

and higher (above average in size) when using the later-occurring minimum. For smoothed monthly mean sunspot number through October 1997 (t = 17 or 14 mo, respectively), having a provisional value of 32.0, the earlier minimum date projects an RM of 110.3 ± 33.1, while the later minimum date projects one of 137.2 ± 41.2. The projection is slowly decreasing in size using the earlier onset date, while it is slowly increasing in size using the later onset date.

TP—1998–208592 August 1998

Volcanism, Cold Temperature, and Paucity of Sunspot Observing Days (1818–1858): A Connection? R.M. Wilson. Space Sciences Laboratory.

During the interval of 1818–1858, several curious decreases in the number of sunspot observing days per year are noted in the observing record of Samuel Heinrich Schwabe, the discoverer of the sunspot cycle, and in the reconstructed record of Rudolf Wolf, the founder of the now familiar relative sunspot number. These decreases appear to be nonrandom in nature and often extended for 1–3 yr (or more). Comparison of these decreases with equivalent annual mean temperature (both annual means and 4-yr moving averages), as recorded at Armagh Observatory (Northern Ireland), indicates that the temperature during the years of decreased number of observing days trended downward near the start of each decrease and upward (suggesting some sort of recovery) just before the end of each decrease. The drop in equivalent annual mean temperature associated with each decrease, as determined from the moving averages, measured about 0.1–0.7 °C. The decreases in number of observing days are found to be closely related to the occurrences of large, cataclysmic volcanic eruptions in the tropics or northern hemisphere. In particular, the interval of increasing number of observing days at the beginning of the record (i.e., 1818–1819) may be related to the improving atmospheric conditions in Europe following the 1815 eruption of Tambora (Indonesia: 8°S), which previously has been linked to "the year without a summer" (in 1816) and which is the strongest eruption in recent history, while the decreases associated with the years of 1824, 1837, and 1847 may be linked, respectively, to the large, cataclysmic volcanic eruptions of Galunggung (Indonesia; 7°S) in 1822, Cosiguina (Nicaragua) in 1835, and, perhaps, Hekla (Iceland; 64°N) in 1845. Surprisingly, the number of observing days per year, as recorded specifically by Schwabe (from Dessau, Germany), is found to be linearly correlated against the yearly mean temperature at Armagh Observatory (r = 0.5 at the 2 percent level of significance); thus, years of fewer sunspot observing days in the historical record seem to indicate years of probable cooler climate, while years of many sunspot observing days seem to indicate years of probable warmer climate (and vice versa). Presuming this relationship to be real, one infers that the observed decrease in the number of observing days near 1830 (i.e., during "the lost record years" of 1825 to 1833) provides a strong indication that temperatures at Armagh (and, perhaps, most of Europe, as well) were correspondingly cooler. If true, then, the inferred cooling may have resulted from the eruption of Kliuchevskoi (Russia; 56°N) 1829.

CP—1998–206899/Vol. 1 January 1998

General Public Space Travel and Tourism—Volume 1 Extreme Summary. Daniel O'Neil, Compiler, Ivan Bekey,* John Mankins,* Tom Rogers,** and Eric Stallmer,** Editors. *NASA Headquarters, **Space Transportation Association.

Volume One of the General Public Space Travel and Tourism Workshop is a summary of the findings of the participants. This document provides an overview of the infrastructure requirements, policy and regulation needs, and potential near term activities.

Volume II contains the detailed findings of the multi-day workshop conducted at Georgetown University, Washington, DC.

CP—1998–206900 January 1998

Tether Technology Interchange Meeting, J.K. Harrison, Compiler. Program Development Directorate.

19980202346N

This is a compilation of 25 papers presented at a tether technical interchange meeting in Huntsville, AL, on September 9–10, 1997. After each presentation, a technical discussion was held to clarify and expand the salient points. A wide range of subjects was covered including tether dynamics, electrodynamics, space power generation, plasma physics, ionospheric physics, towing tethers, tethered reentry schemes, and future tether missions.

CP—1998–206960 February 1998

Life and Microgravity Spacelab (LMS) Final Report. J.P. Downey, Compiler.

19980206462N

This document reports the results and analyses presented at the Life and Microgravity Spacelab (LMS) One Year Science Review meeting. The science conference was held in Montreal, Canada, on August 20–21, 1997, and was hosted by the Canadian Space Agency. The LMS payload flew on the Space Shuttle Columbia (STS–78) from June 20–July 7, 1996. The LMS investigations were performed in a pressurized Spacelab module and the Shuttle middeck. Forty scientific experiments were performed in fields such as fluid physics, solidification of metals, alloys, and semiconductors, the growth of protein crystals, and animal, human, and plant life sciences. The results demonstrate the range of quality science that can be conducted utilizing orbital laboratories in microgravity.

CP—1998–208536 July 1998

The 1997 NASA Aerospace Battery Workshop. J.C. Brewer, Compiler. NASA Aerospace Flight Battery Systems Program.

This document contains the proceedings of the 30th annual NASA Aerospace Battery Workshop, hosted by the Marshall Space Flight Center on November 18–20, 1997. The workshop was attended by scientists and engineers from various agencies of the U.S. Government, aerospace contractors, and battery manufacturers, as well as international participation in like kind from a number of countries around the world.

The subjects covered included nickel-cadmium, nickel-hydrogen, nickel-metal hydride, lithium, lithium-ion, and silver-zinc technologies, as well as various aspects of nickel electrode design.

CR—97–205192 July 1997
Standardized Methods for Electronic Shearography—Final Technical Report for Period June 14, 1996 through June 14, 1997. NAS8–38609, D.O. #167. University of Alabama in Huntsville.

CR—97–205193 November 1996
FNAS/Cosmic Ray-Air Shower Measurement From Space Cosmic Ray Research—Final Report, January 18, 1996–November 17, 1996. NAS8–38609, D.O. #161. University of Alabama in Huntsville.

CR—97–205194 January 1995
FNAS/Production Cross Sections of Hadronic Resonances—Final Report, September 20, 1994–January 1, 1995. NAS8–38609, D.O. #124. University of Alabama in Huntsville.

CR—97–205195 June 1997
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CR—97–205196 June 1997
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CR—97–205197 April 1997
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CR—1998–205199 April 1998
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CR—1997–205200 June 1997
Optical Fabrication and Measurement: AR&C and NGST—Final Report. September 11, 1996–June 30, 1997. NAS8–38609, D.O. #176. University of Alabama in Huntsville.

CR—1998–205201 May 1997
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CR—1998–205202 April 1998
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CR—1998–205203 November 1997
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CR—1998–205204 November 1997
Current Collection in a Magnetic Field—Final Report. NAS8–38609, D.O. #183. University of Alabama in Huntsville.

CR—1998–205205 October 1996
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CR—1998–207894 May 1997
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CR–1998—207895 May 1997
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CR–1998—207896 June 1997
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CR–1998—207897 May 1997
Evaluation of Optimum HgZnTe Crystal Growth Parameters and USML–2 Flight Support—Final Report, December 2, 1996–December 1, 1996. NAS8–40429.University of Alabama in Birmingham.

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Cosmic Ray Energy Determination by the Reduced-Opening Angle Method—Final Report. NAS8–38609, D.O. #163. University of Alabama in Huntsville.

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